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Traditional herbal remedies used by Kuruchia communities in Wayanad district of Kerala to Combat stored Grain pests

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Abstract
Located in Wayanad District's forests, the Kurichia tribe has an extensive array of traditional ecological knowledge regarding the use of herbal medicine in their agricultural activities. This study documents the traditional ways that the Kurichia tribe protects its stored grains from pest infestations using herbs. Data were collected via field observations, interviews with local village elders, and literature on ethnobotany to provide a comprehensive view of the methods used. The results indicate that the Kurichia tribe uses native plant sources and natural substances (i.e., not man-made) for environmentally friendly pest control. The people of this tribe routinely use powders made from plants or extracts of leaves, as well as smoke from the burning of both medicinal and aromatic plants, as repellents to all insects. In addition to these repellent methods, dried leaves, ash, and crushed tubers such as wild arrowroot also assist in deterring pests found in storage, while preventing damage to stored grains. Furthermore, many times when storing grains, Kurichia people line the inside of their containers with bamboo and cover grains with natural plant materials, such as banana spathes, to create a physical barrier as well as a chemical barrier against all pests. These indigenous methods used by the Kurichia tribe are sustainable, economical, and have no chemical residue; they demonstrate an in-depth understanding of the natural environment. Herbal pest control methods are utilized by the Kurichia community and demonstrate a commitment to organic farming principles focused on conserving biodiversity; however, this important form of traditional knowledge is being eroded through modernization and changing livelihood patterns. The research highlights that it is essential to document and conserve the ethnobotanical practices of the Kurichia, as they present viable alternatives to synthetic pesticides and support sustainable agriculture. The integration of traditional knowledge with modern scientific methodologies can improve food security and sustainability in rural and tribal settings.

Keywords: Herbal, remedies, kuruchia, wayanad, Kerala, stored grain pests

Introduction

India has a rich cultural heritage that includes a vast amount of traditional knowledge about agriculture. This knowledge has been handed down from generation to generation through traditional practices that developed in harmony with the natural world and the environment over time (Altieri, 1995) [1]. Ethnobotanical knowledge held by different ethnic groups, particularly tribal people, accounts for a considerable amount of the indigenous agricultural knowledge that is sustainable and eco-friendly (Gupta, 2016) [2]. As an example, the Kurichia in Wayanad have developed an extensive understanding of how to manage natural resources wisely through the use of indigenous methods of pest control using plants. The Kurichia have developed many indigenous ways to manage stored grains to protect them from pests, including the use of dried plant leaves, herbs/powders, smoke fumigation and natural storage structures designed to minimize the chance of insect infestations that would ruin the grains.

Tribal communities, like the Kurichia, have used their ethnobotanical knowledge of plants to protect their food from post-harvest losses due to stored grain insect pests. In rural and tribal communities, losses resulting from stored grain pests range from 10% to 30% (FAO, 2011). In order to control these pests, conventional pest control methods rely heavily on the use of synthetic chemical pesticides. While synthetic pesticides effectively control pests, their use can have a considerable negative impact on the environment, public health and the economy due to chemicals leaking into the environment and the development of pest resistance to chemicals, as well as increased cost due to treatment requiring the use of chemicals (Isman, 2006; Koul *et al*., 2008) [9, 11].

Kurichia people use their knowledge of plants in addition to their agricultural and archery skills when developing their indigenous ways to protect their stored grains. With the indigenous methods they use, the Kurichia people have developed eight indigenous pest management methods that are environmentally safe, biodegradable and economically feasible to use locally and within their culture. Some examples of plants that have repellent effects, antifungal properties, or antimicrobial activity are neem, turmeric, and aromatic herbs. These plants have been passed down orally through many generations and are a significant part of the socio-cultural structure of this community. (Mana *et al*., 2023) [13]. Many of these traditional knowledge systems are now being systematically eroded through the rapid pace of modernization, deforestation, and increased use of chemical pesticides. Documentation, validation and integration of these Indigenous practices into modern pest management practices have become increasingly urgent. The current research will identify and document the traditional methods of using herbal plants that the Kurichia people of Wayanad

county, Kerala, use to control pests in their stored grains. By documenting these practices the intent of the research is to promote sustainable farming, encourage the use of environmentally friendly pest control options and assist in the preservation of Indigenous knowledge systems. In addition, it is important to recognize that the traditional methods of storing grains should not be viewed solely as technical means of storage but rather as an extension of their cultural identity and ecological wisdom. The way these people view their agricultural systems demonstrates an integrated holistic approach to agriculture, wherein crop production, storing and protecting crops are seen as parts of an interrelated system and not as components of a separate system. Plant material can help to keep insects away from stored crops. For many years, people have been using different types of plants to keep their crops free from bugs, and they have found that some types of plants work better than others, depending on the time of year you harvest your crops and what type of food you are storing (Trivedi *et al*., 2018) [23]. In Wayanad district, where it is hot and humid, there are many types of bugs that like to eat food stored in warehouses, such as beetles, weevils and moths. To keep these bugs from getting into their crops, the Kurichia people take preventative measures before they even harvest their crops. Three of the most important preventative measures they use are drying the grains outside in the sun, cleaning out the buildings where they store their grains and using things like wood ash to hold moisture in the buildings where they store their grains. These three things help prevent bugs from getting into the grains and will also increase the amount of time that you can store the grains without losing any of their nutritional value (Singh & Sharma, 2012) [18]. By placing different botanicals such as neem leaves, sweet flag or spices on top of the grains, the Kurichia people know that the botanicals contain plant chemicals that kill or repulse insects when they come in contact with the botanicals. The practice of layering the grains with dried leaves or mixing the grains with powdered botanicals also help keep the grains safe from bugs (Obeng-Ofori, 2007; Bezabih *et al*., 2022) [3, 15]. The Kurichia people also use smoke from burning certain herbs to fumigate the buildings where they store the grains to kill any bugs or microorganisms that may be in the building, thus making it impossible for bugs or microorganisms to live in the building Joseph B, Sujatha S (2012). (Joseph & Sujatha, 2012) [10]

Indigenous methods of agriculture have effectively been used but are not usually well documented or widely employed in modern commercial agriculture (Altieri, 1995; Gupta, 2016) [1, 2]. The lack of scientific evidence for these types of agricultural methods makes it difficult to verify their validity as there remains a gap between traditional knowledge of agriculture and modern scientific methods of pest control. Closing this gap in knowledge will provide opportunities for new pest control options that are inexpensive to implement, environmentally sustainable, and can be adapted to local conditions, especially for smallholder and marginal farmers. This research not only documents the traditional use of plant-based medicines used by the Kurichia community but also highlights the relevance of these types of medicines in the current practice of sustainable agriculture and protecting the environment. (Singh *et al*., 2023) [19]. Integrating traditional knowledge and techniques with scientific research is likely to lead to alternative methods of pest control that are less reliant upon the use of synthetic chemical pesticides, while also ensuring the protection of biodiversity and the cultural heritage of indigenous peoples.

Indigenous Knowledge Systems and Ethnobotany

Indigenous knowledge systems provide the basis for sustainable agricultural practices by tribal communities in India through the cumulative body of knowledge, practices, and beliefs created as a result of their long-term engagements with nature (Gupta, 2016; Altieri, 1995) [1, 2]. Ethnobotany, the study of the interactions between people and plants, shows how Indigenous communities make use of plants in their area for food, medicine, and produce protection and storage. The Kurichia community has an extensive knowledge of plants that has been developed over many centuries due to their close relationship with nature, especially at the interface of agriculture and forests. This knowledge includes identifying plants that can repel certain insects, when particular plant resources are available, and how to use the plants. According to Gupta (2016) [2], traditional and grassroots innovations can strengthen rural economies by increasing their resiliency and decreasing their dependence on outside sources of assistance. Generally, Indigenous knowledge systems are location-specific, based on significant levels of biodiversity, and rooted in the local culture; as a result, they are very adaptable, environmentally safe, and have high levels of relevance to issues involving climate variability and preserving/maintaining the environment (Bezabih *et al*., 2022; Trivedi *et al*., 2018) [3, 23].

Stored Grain Pests and Post-Harvest Losses

The problem posed by stored grain pests significantly affects tropical and subtropical areas, resulting in huge amounts of loss after the harvest, both quantitatively and qualitatively (Upadhyay *et al*., 2010) [24]. Wayanad district, for example, has a combination of high humidity, warm temperatures and the traditional way of storing grains and these factors provide the best possible environment for insects of all kinds to develop. The main pests found in stored grains include; the rice weevil, the lesser grain borer, and the storage moths which cause the loss of weight through feeding on the grain, contamination through excrement and dead bodies, decrease in germination capacity, and deterioration of quality from a nutritional standpoint (Campolo *et al*., 2018) [5]. Food and Agriculture Organization (2011) [8] states that the average loss from just post-harvest storage in developing nations alone ranges from 10 to 30 percent of the total harvest producing a significant threat to food security and farmer livelihoods across these areas. For tribal communities that rely on subsistence farming, these losses will directly affect both household food supply and the stability of their economies. In addition, pest infestations will also lead to other secondary problems such as fungal growth and contamination with mycotoxins which create additional health concerns (Singh *et al*., 2021) [20].

Limitations of Chemical Pest Control

The use of synthetic pesticides and fumigants, including phosphine and methyl bromide, is prevalent in modern

agriculture for managing pests in storage. Although they are effective in the short term, they pose numerous challenges to the environment and society's economy. Long-term use of these pesticides can result in environmental pollution, bioaccumulation, resistance development by pests and the destruction of many beneficial organisms that would otherwise help in a natural pest management practice. Pesticide residues left on food grains can have serious consequences for human health because of the risk of development of respiratory diseases, neurological conditions and cancer. Mahatma Gandhi (1997) expressed the need for self-sustaining and living in harmony with nature, which includes using available resources compatible with local production methods, which aligns closely with the principles of traditional pest management. As chemical pesticides are also generally expensive and difficult for marginal farmers and tribal peoples to access, alternative methods based on traditional knowledge will be increasingly viable.

Traditional Herbal Remedies for Pest Management

The Kurichia community uses an array of plant materials in their grain storage efforts, demonstrating a strong understanding of the local plants' ability to prevent pest damage to their grains through the use of these natural substances. Examples of plant materials that are often utilized are neem leaves and/or oil from the neem tree, turmeric, sweet flag, ash, and different extracts from medicinal plants. Through the use of bioactive compounds found in these plants, such as alkaloids, flavonoids, terpenoids, and phenolics, the Kurichia community is able to exhibit insecticidal, repellent, antifeedant, and growth-inhibiting effects on stored grain pests. Isman (2006) [9] describes plant secondary metabolites as having a powerful impact on disruptive insect behavior and physiology without contributing to environmental destruction (Isman, 2006; Koul *et al*., 2008) [9, 11]. In order to create a hostile environment for insects, the Kurichia people use various methods, including mixing dried powder or leaves with grains, adding plant material to storage containers, and fumigating storage areas with herbal smoke. The usage of these methods leads to lower rates of insect infestation and improved grain quality. The greatest benefit of these techniques is that they are biodegradable, non-toxic, and fit within the realm of organic farming practices.

Storage Techniques and Preventive Measures

Along with employing herbal remedies, the Kurichia community utilizes multiple preventive measures that improve the effectiveness of their pest control methods. One of the most important ways to minimize the risk of pests infesting grains is through proper post-harvest handling procedures, such as thoroughly drying grain by exposing it to the sun before storing it, because most insects that infest stored food require a high relative humidity to survive. Storage units constructed using bamboo, wood, clay and other locally available materials were designed to allow for air circulation during grain storage, as well as reduce the amount of pests that can get into the storage unit. The use of ash as an outer layer of grain is also used to help absorb moisture and block insect passage into the grain. By using plant leaves to cover grains and/or using sealed containers to store grains, the grains' exposure to pests is further reduced. Singh and Sharma (2012) [18] recommend that when traditional storage units are constructed in conjunction with botanical pest control methods that the resulting reduction in grain losses and the quality of stored grain will be greatly improved over a longer period of time. As this example demonstrates, the Kurichia people employ an integrated approach to pest management by utilizing a combination of physical, biological, and cultural methods that are both economically viable and environmentally sustainable.

Need for Documentation and Scientific Validation

Traditional farming practices, while proven to work and be sustainable, are increasingly being replaced by modern mainline agriculture inputs because of the changing socio-economic climate, urbanisation and the influence of commercial agriculture. This leads to the gradual destruction of native means of knowing. Therefore, it is essential to systematically document traditional agroecological practices before they are lost, especially ethnobotanical and pest-management practices. Documenting traditional practices through scientific methods, such as by laboratory and field trials, can help to establish the effectiveness of herbal remedies, appropriate dosages and their modes of action. According to Easwaran (2007) [7], there is a need to integrate traditional ways of knowing with modern scientific approaches and to utilize ancient wisdom for solving present-day problems. By providing scientific validation, the credibility of, and means to develop standardized, scalable, and policy-supported solutions for sustainable agricultural practices will be increased.

Relevance to Sustainable Agriculture

The Kurichia community's pest control methods are mainly based on the principles of sustainable agriculture. These principles include being environmentally friendly, economically practical, and socially responsible. The use of plants from the local area helps Kurichias decrease their dependence on artificial chemicals and other inputs to produce fewer costs, reduce damage to ecosystems and promote biodiversity by maintaining and planting native plants. According to Altieri (1995) [1], traditional knowledge-based agroecology will be critical in increasing the capacity of agriculture to adapt to environmental stress, such as climate change. Lastly, Kurichials' pest control methods promote healthy food by eliminating the residues of chemical agricultural products and supporting organic farming systems. Therefore, combining traditional ecological knowledge (TEK) with modern science can be a huge contributor to sustainable agriculture over the long term, enhancing food security and sustaining cultural diversity.

The effect of botanical biopesticides on seed quality

Numerous biotic and abiotic variables, including genotype, seed moisture content, storage conditions, and pests (e.g., fungus, bacteria, insects, etc.), influence seed quality (Bewley *et al*., 2013; Maheswari, 2023). When saving seeds for planting at a later date, it is extremely important that they remain viable and in good condition. Optimal crop output and the preservation of seeds susceptible to the unpredictable genetic degradation depend on keeping seed quality intact throughout storage. Seeds are less likely to germinate if storage insect pests have eaten away at their viability and vigor. Research has shown that botanicals do

not degrade seed quality in any way (Bezabih *et al*., 2022) [3]. Abiotic variables like storage conditions, pests (fungi, bacteria, insects, etc.), and biotic factors like genotype impact seed quality. When saving seeds for planting at a later date, it is extremely important that they remain viable and in good condition. Optimal crop output and the preservation of seeds susceptible to the unpredictable genetic degradation depend on keeping seed quality intact throughout storage. Seeds are less likely to germinate if storage insect pests have eaten away at their viability and vigor (Upadhyay *et al*., 2010) [24]. Botanicals did not negatively impact grain or seed quality, according to many research (Obeng-Ofori, 2007; Trivedi *et al*., 2018) [15, 23]. Therefore, organic pest management (IPM) and botanicals are complementary approaches to controlling insect pests.

Types of botanicals used in food storage protection

To control pests in storage, one can employ botanicals, which are plants or products made from plants that contain active chemicals. Not only are these plants used medicinally, but they are also spices. The usage of spices dates back to ancient times, when they were not only used to flavor food but also to keep pests at bay (Koul *et al*., 2008) [11]. Although crushed or dried spice pieces were traditionally used to season or blend with preserved foods, new research into extracts or oils has shown encouraging outcomes. Herbal and Non-Medicinal Plants: Spices are not the only botanicals used to combat stored-product pests. There are a variety of plants that may be utilized for both medicinal and food preservation purposes. Some of these plants have anti-storage insect properties, while others target specific human ailments. The leaf extracts of all the plants—including Prosophis sp., Nerium sp., Ocimum sp., Acalypha sp., Catharanthus sp., and Vitex sp.—strongly discouraged the pulse beetle from laying its eggs (Maheshwari *et al*., 2023).

Most significantly, the egg viability was reduced by 61.7% when exposed to Vitex sp. leaf extract, followed by 56.7% when exposed to Catheranthus sp. leaf extract. The emergence of adults was reduced by 85.0% when seeds treated with Vitex sp. at a concentration of 5%, then by 83.7% when treated with Acalypha sp., 73.3% when treated with Nerium sp., 70.0% when treated with Ocium sp., 68.7% when treated with Prosphis sp., and 68.0% thereafter. Research on the effectiveness of A. mexicana, P. juliflora, and T. purpurea plant powders as repellents against T. castaneum was carried out. All of the plant powders, on the whole, acted as repellents (Trivedi *et al*., 2018; Souto *et al*., 2021) [21, 23]. In comparison to other treatments, pyrethrum-treated bean seeds lost less weight had a lower proportion of damaged seeds, and a higher number of holes per seed. Using garlic instead of no pesticides was the most effective (Obeng-Ofori, 2007) [15].

Fig 1: Strategies for controlling pests that prey on stored grain (Koul *et al*., 2008; Bezabih *et al*., 2022) [3, 11].

In regard to the percentage of damaged seeds, the number of holes per seed, the rate of seed germination, and weight loss. At 10.0 g/kg of seed, the sweet flag rhizome powder significantly surpassed the untreated control by the conclusion of the tenth month of storage. In contrast to the treated seedlings, which exhibited significantly greater germination percentage (87.00%), vigor index (2694), and dry weight of seedlings (329.50 mg), the untreated control group exhibited poorer electrical conductivity (0.488 dSm-1) and an infestation rate of 3.33% among insects. According to Derbalah (2012), the botanical extracts that were determined to have the most effective effects against T. granarium in terms of mortality and adult progeny were Cassia fistula, Bauhinia purpurea, Chrysanthemum frutescens, Euonymus japonicus, and Caesalpiniagilliesii. The most effective botanical extract against T. granarium was C. senna. Many pests can't stand the taste of sugar apple seeds. Chemicals in the plant's leaves prevent the development of insects that feed on grain storage. Vittallariaparadoxa, a plant-based biopesticide, has shown encouraging results in controlling the Callosobruchus maculates, a kind of pulse beetle. Protect stored grain from insects with the use of Indian privet leaves. The bitter gourd, karanja, and urmoi seed extracts preserved the wheat grains for up to 30 days.

The plant species such as Artemisia nilagirica, Holoptelea integrifolia, Cassia fistula, Capsicum annuum, Murraya koenigii, and Capsicum frutescens further strengthens the evidence that the Kurichia community utilizes a highly diverse range of botanicals for stored grain pest management. Many of these plants, particularly Artemisia nilagirica and Cymbopogon citratus, are rich in essential oils that act as strong fumigants and repellents, while chilli species (Capsicum annuum and Capsicum frutescens) provide irritant and toxic effects due to capsaicin content (Koul *et al*., 2008; Campolo *et al*., 2018) [5, 11]. The use of Murraya koenigii and Holoptelea integrifolia reflects reliance on locally available aromatic and medicinal plants, which release volatile compounds deterring insect infestation. Overall, the expanded list demonstrates that traditional pest control practices are not limited to a few species but involve a wide spectrum of plants with complementary modes of action. This diversity enhances the effectiveness and sustainability of indigenous pest management systems, supporting findings by Isman (2006) and Gupta (2016) [2, 9] that plant-based pest control strategies are both ecologically safe and scientifically valid.

Materials and Method: Study area

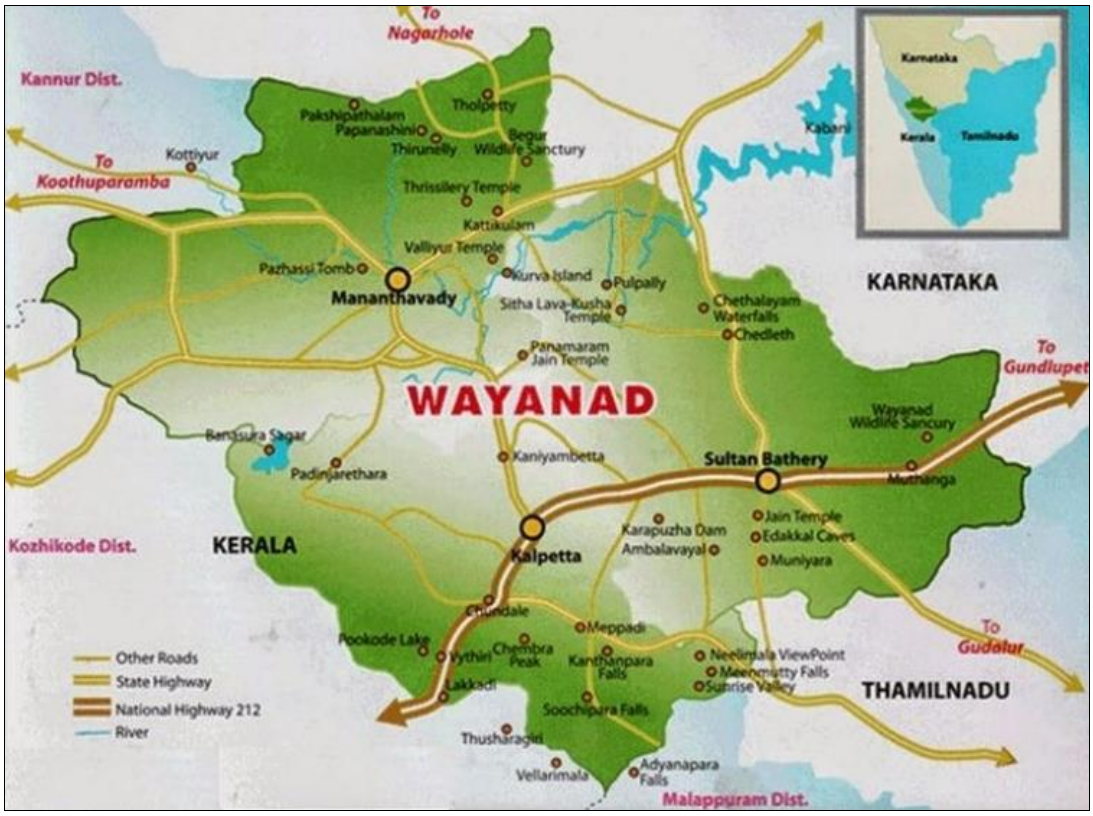


Fig 2: Study area

The study was conducted in Wayanad district, known for its great diversity of biological phenomena and sizable indigenous groups.

Latitude 11°27’00" N and 11°58’35" N

Longitude 75°47’50" E and 76°26’35" E

Geographical Area 2129 sq km

The Kurichia group was the focus due to their cultural and agricultural richness, as well as their abundant folk wisdom related to plant use. The qualitative/ethnobotanical method was employed to document and assess indigenous wisdom regarding the use of herbs for pest control in stored cereals. This strategy allowed for an exhaustive investigation of indigenous knowledge systems in the socio-cultural and ecological settings of the Kurichia people. To gather primary data, an extensive amount of fieldwork took place using semi-structured interviews, focus group meetings and participant observation. Tribal elders, experienced farmers, and local experts were identified as key participants because

of their thorough knowledge about traditional agricultural methods. Interviews were conducted in an open-ended manner, in order to provide as complete as possible a set of characteristics regarding the plant used, how it was prepared, how it was applied, and the results of application, of each of the herbal products used for pest management in Kurichia households. In order to be able to check the reliability of data collected from focus group discussion, the focus group discussions were held. Also, by seeing how grain stored was constructed and observing how the community pest controls were done, we could understand how to apply these same methods. In addition to focus groups, we also gathered secondary data from books, peer reviewed articles and other reports and here to compare and support our conclusion with existing scientific literature on grain pest management and ethnobotany. we used purposive sampling (50 people) to ensure we are interviewing people who have enough of this traditional knowledge and provide relevant and reliable to collect good data from them. To ensure validity of data collection, we conducted field surveys to identify what plants the participants used and later confirmed valid by referencing standard taxonomic literature or botanical expert opinion. The data collected from the study were analysed using descriptive analysis, where the plant species found were classified into categories based on usage and method of use. Alongside these analyses the ethnobotanical indices of frequency of citation and use-value were used to determine the relative significance of the various species. Ethical protocols were adhered to during the study including obtaining prior informed consent from participants by using format of kerala biodiversity board and being respectful of the cultural sensitivity of the indigenous knowledge being discussed. While the research gives a good insight to traditional pest control practices, its limitations include geographical boundaries and reliance on memory recall for the transfer of traditionally based practices, which are not always equally influenced by locals/ informants. Nevertheless; the methodology used provides a culturally appropriate and methodical approach towards documenting the indigenous practices, which will aid in promoting sustainable and environmental friendly means by which to protect stored grains. Muhammad B Y. (2023) [14]. The plant specimens were identified with the help of standard flora(Ansari 1985) and Herbaria.

Results and Discussion

The current research has recorded an extensive database of the traditional herbal knowledge that exists within the Kurichia people in Wayanad district with respect to pest control of stored grains. The research findings establish that many of the indigenous practices are economically viable, sustainable, and well suited for the environmental conditions in the region. Fifteen plant species with different taxonomic families have been identified as commonly used for the purpose of protecting stored grains from insect pests. The primary methods of pest control within this tradition include both preventative measures (i.e., via botanical-based repellents) and physical barriers (i.e., using toxic substances).

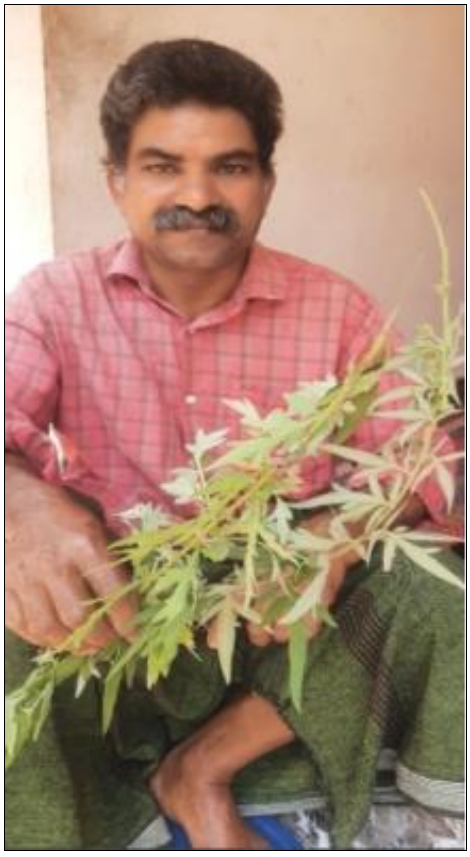


Fig 3: An informant

Fig 4: An Informant- Padmashree cheruvayal Raman

Table 1: List of Plant Species Used by Kurichia Communities Showing Insecticidal Activity Against Stored Grain Pests

S. No.	Botanical Name	Common Name	Family	Plant Part Used	Traditional Application Method	Mode of Action	Target Pests
1	*Azadirachta indica*	Neem	Meliaceae	Leaves, seeds	Leaves mixed with grains; oil coating	Repellent, growth regulator	Weevils, beetles
2	*Curcuma longa*	Turmeric	Zingiberaceae	Rhizome	Powder mixed with grains	Repellent, antimicrobial	Moths, beetles

3	*Acorus calamus*	Sweet flag	Acoraceae	Rhizome	Powder applied in storage	Toxic, insecticidal	Weevils
4	*Ocimum tenuiflorum*	Tulsi	Lamiaceae	Leaves	Leaves layered with grains	Repellent	Moths
5	*Cymbopogon citratus*	Lemongrass	Poaceae	Leaves	Leaves kept in storage	Repellent (aroma)	Storage insects
6	*Vitex negundo*	Nirgundi	Lamiaceae	Leaves	Used as grain cover	Repellent	Beetles
7	*Piper nigrum*	Black pepper	Piperaceae	Seeds	Powder mixed with grains	Toxic	Weevils
8	*Allium sativum*	Garlic	Amaryllidaceae	Bulb	Crushed bulbs placed in storage	Insecticidal	Borers
9	*Zingiber officinale*	Ginger	Zingiberaceae	Rhizome	Powder mixed with grains	Repellent	Storage pests
10	*Eucalyptus globulus*	Eucalyptus	Myrtaceae	Leaves	Used for fumigation	Fumigant	Beetles
11	*Lantana camara*	Lantana	Verbenaceae	Leaves	Leaves placed in containers	Toxic	Insects
12	*Calotropis gigantea*	Milkweed	Apocynaceae	Leaves	Used as lining material	Toxic	Storage pests
13	*Annona squamosa*	Custard apple	Annonaceae	Seeds	Powder mixed with grains	Strong insecticidal	Weevils
14	*Melia azedarach*	Chinaberry	Meliaceae	Leaves	Mixed with grains	Repellent	Beetles
15	*Oryza sativa* (ash)	Rice ash	Poaceae	Husk/ash	Mixed with grains	Physical barrier	All pests
16	*Artemisia nilagirica*	Indian wormwood	Asteraceae	Leaves	Dried leaves mixed or fumigated	Repellent, fumigant	Moths, beetles
17	*Holoptelea integrifolia*	Indian elm	Ulmaceae	Leaves	Leaves placed in storage	Repellent	Storage insects
18	*Cassia fistula*	Golden shower	Fabaceae	Leaves, pods	Powder or leaf layering	Insecticidal	Grain pests
19	*Capsicum annuum*	Chilli	Solanaceae	Fruits	Powder mixed with grains	Irritant, repellent	Weevils
20	*Murraya koenigii*	Curry leaves	Rutaceae	Leaves	Leaves placed with grains	Repellent (volatile oils)	Beetles
21	*Capsicum frutescens*	Red chilli	Solanaceae	Fruits	Powder applied in storage	Toxic, irritant	Storage insects

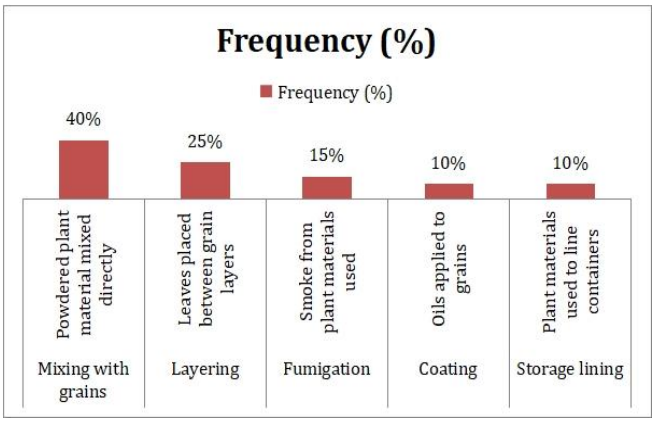
Table 2: Habit of Plant Species Used for Stored Grain Pest Control

S. No.	Botanical Name	Family	Plant habit
1	*Azadirachta indica*	Meliaceae	Tree
2	*Curcuma longa*	Zingiberaceae	Herb
3	*Acorus calamus*	Acoraceae	Herb
4	*Ocimum tenuiflorum*	Lamiaceae	Shrub
5	*Cymbopogon citraus*	Poaceae	Grass
6	*Vitex negundo*	Lamiaceae	Shrub
7	*Piper nigrum*	Piperaceae	Climber
8	*Allium sativum*	Amaryllidaceae	Herb
9	*Zingiber officinale*	Zingiberaceae	Herb
10	*Eucalyptus globulus*	Myrtaceae	Tree
11	*Lantana camara*	Verbenaceae	Shrub
12	*Calotropis gigantea*	Apocynaceae	Shrub
13	*Annona squamosa*	Annonaceae	Tree
14	*Melia azedarach*	Meliaceae	Tree
15	*Oryza sativa* (by-product)	Poaceae	Crop residue
16	*Artemisia nilagirica*	Asteraceae	Shrub
17	*Holoptelea integrifolia*	Ulmaceae	Tree
18	*Cassia fistula*	Fabaceae	Tree
19	*Capsicum annuum*	Solanaceae	Herb
20	*Murraya koenigii*	Rutaceae	Shrub
21	*Capsicum frutescens*	Solanaceae	Shrub

The use of various types of plants is supported by the data. The herbaceous and shrubby types of plant growth were the most common of the data collected from plants used in household remedies. The majority of plant parts used were leaves and rhizomes, which suggest they are readily available and are likely to contain a higher amount of bioactive compounds than other plant forms. The high prevalence of neem, turmeric and other well-known insecticidal plants was indicative of their current insect repellent capabilities (such as neem oil/Sampe; turmeric powder), as well as their abundance in the immediate region.

Table 3: Methods of Application of Herbal Remedies

S. No.	Method	Description	Frequency (%)
1	Mixing with grains	Powdered plant material mixed directly	40%
2	Layering	Leaves placed between grain layers	25%
3	Fumigation	Smoke from plant materials used	15%
4	Coating	Oils applied to grains	10%
5	Storage lining	Plant materials used to line containers	10%



Mixing powder forms of plant matter with grains appears to have been the predominant method of application to crops due to being relatively easy and effective. Other methods include layering and fumigating, which provide for both a preventive and curative approach. These strategies constitute an Integrated Pest Management Strategy based on indigenous practices.

Table 4: Mode of Action of Selected Plant Species

S. No.	Plant Name	Mode of Action
1	Neem	Repellent, growth inhibitor
2	Turmeric	Antimicrobial, repellent
3	Sweet flag	Toxic, neurotoxic
4	Tulsi	Fumigant, repellent
5	Garlic	Antimicrobial, insecticidal
6	Lemongrass	Repellent
7	Black pepper	Toxic
8	Lantana	Toxic
9	Custard apple	Strong insecticidal
10	Eucalyptus	Fumigant

Multiple mechanisms of pest management were found from the results, including repellency, toxicity and growth inhibition; hence, through the variety of actions, there is less risk of developing resistant pests and increased efficacy. The presence of plants with multiple bioactive compounds demonstrates that the Kurichia Community has a greater understanding of the complexity associated with controlling pests.

Table 5: Target Stored Grain Pests Identified

S. No.	Pest Name	Scientific Name	Type of Damage
1	Rice weevil	*Sitophilus oryzae*	Internal feeding
2	Lesser grain borer	*Rhyzopertha dominica*	Grain boring
3	Grain moth	*Sitotroga cerealella*	Larval feeding
4	Red flour beetle	*Tribolium castaneum*	Powdering grains
5	Pulse beetle	*Callosobruchus chinensis*	Seed damage

There is evidence of several types of storage pests regularly infesting grain before or during the harvest process. The herbal remedies used by the Kurichia community are highly effective against different types of pests, which shows that there is ample evidence supporting their effectiveness as well as flexibility for use in varying environmental conditions.

Table 6: Perceived Effectiveness of Herbal Remedies

S. No.	Effectiveness Level	Percentage of Respondents
1	Highly effective	55%
2	Moderately effective	30%
3	Less effective	15%

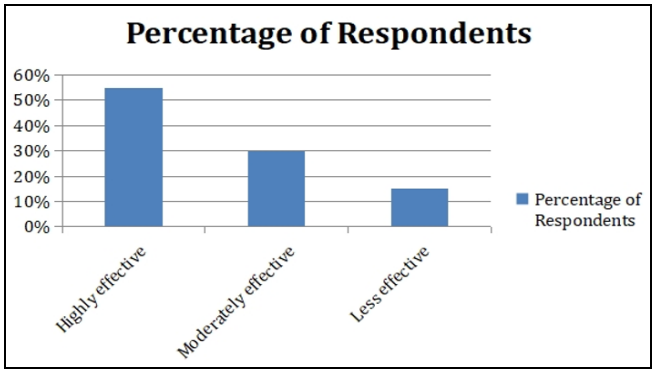


Fig 6: Percentage of Respondents

The majority of respondents (55%) viewed herbal treatments as extremely effective, reflecting a strong level of community trust in traditional methods of healing. The low percentage of respondents who rated these treatments as not very effective indicates that these methods are likely to work well based on local conditions. Variability in effectiveness may be due to differences in how the treatments are applied, stored and the degree of infestation present.

Discussion

The results from this study show how deeply rooted and relevant are indigenous knowledge systems (IKS) related to stored grain pest management as practiced by the Kurichia community in Wayanad district. The number of plant species identified and the many ways these plants can be applied demonstrate an extensive, experiential-based system similar to modern-day integrated pest management systems. The primary use of local plants such as neem, turmeric, and sweet flag indicates that this method of pest management evolved as an adaptive ecological strategy based on the sustainable use of resources. The effectiveness of these herbal pest-control methods can be accounted for by the presence of bioactive compounds (e.g., alkaloids, terpenoids, and phenolics) in these plants, all of which exhibit insecticidal, repellent, and growth-regulatory effects. Similar research results were documented by Murray B. Isman (2006) [9], who noted the significant impact of plant secondary metabolites on disrupting insect feeding, reproduction, and development. Additionally, the multiple methods of pest management reported in the study (i.e., repellent, toxic, and fumigant) suggest that these traditional practices may provide multiple modes of protection for stored goods from many pests. Using a multifunctional method decreases how often resistance develops, which is typically a problem linked to using synthetic pesticides. Additionally, the study showed that preventive measures, such as the use of an appropriate drying process, hygiene in storing materials, and usage of plant-based barriers, have become crucial to the pest management system. The results of this study are consistent with those published by Miguel Altieri in 1995 [1], where he pointed out how agriculture practices can help provide resilience and sustainability for

traditional agricultural systems. In utilizing physical, biological, and cultural components, the Kurichia exhibit a comprehensive understanding of pest management while minimizing their influence on the environment and providing for the safety of food.

In addition to this, the high degree of perceived effectiveness that respondents gave indicates that there is a strong trust in those traditions by the community. This corroborates arguments made by Anil Kumar Gupta (2016) [2], where it has been established that indigenous knowledge systems have cultural importance, practical use, and an economic benefit. The use of herbal products helps to eliminate the need for outside inputs, decrease production costs, and remove risks associated with chemical pesticides in harvesting food grains.

That said, traditional methods have faced challenges from changing times and growing agricultural technologies via the greater usage of chemical pesticides. The continued loss and erosion from traditional knowledge demonstrate the need for documented records and scientific validation to ensure they remain in use in future generations. According to FAO (2011), combining traditional knowledge with contemporary scientific methods may be instrumental in reaching sustainable agriculture and decreasing losses after harvests. This research provides evidence that traditional methods are effective in controlling pest populations by validating their use scientifically and assisting in the standardization of the dosages for different plants, as well as developing new formulations based on them for greater use. Lastly, the Kurichia community's traditional methods of managing pests in stored grains is a powerful demonstration of the use of sustainable, Eco-friendly approaches to pest management that can enhance food security and contribute positively to preserving the environment.

Conclusion

This study focuses on how the Kurichia community of Wayanad district in India uses herbs and other plants to control live insects, as well as the rich traditional knowledge they have about this area. The results of this study showed that there is a wide variety of plants native to the area used for pesticides by people in Wayanad -- including neem, turmeric, and sweet flag. Use of native plants for pesticides is an extension of their use in cooking and medicinal treatment. In addition to using plants for pest control, Kurichia use many of the same methods to control pests as other cultures do, such as properly drying grain before storage, maintaining cleanliness of stored grain, and using natural materials for storing grain. The Kurichia pest management system is multi-faceted; they do not only rely on using plant-derived pesticides, but also use good practices in grain storage to prevent insects from entering the grain storage facility in the first place. Their integrated pest management approach is very similar to modern sustainable agriculture methods.

When using native plants for pest management, their low cost in using them can be attributed to the fact that they are easy to cultivate or harvest, they will break down naturally over time (which makes them environmentally friendly), and they are safe for people to handle or ingest. Additionally, the respondents' perceived effectiveness of this method indicates a very high level of trust in these methods of classifying pests in the way they have traditionally been used. Also, several plants with different modes of action provide potential for greater success in preventing pest infestation and reduce the likelihood of resistance development, which is a major concern with the conventional pest control methods that utilize chemicals. Therefore, the possibility of using plant-based compounds as an alternative to chemically synthesized pesticide products is supported by recent literature regarding the study of the use of plant-derived materials. Therefore, traditional knowledge of the Kurichia herbaceous plants represents a sustainable and constructive method of pest management for protecting stored food products (grain). The promotion and continuation of this traditional knowledge can make substantial contributions to enhancing food security, conserving natural resources, and developing organic and environmentally sound agricultural practices. Further research should be directed towards verifying these methods through planned studies and evaluating their use at the commercial level.

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